6 RBES CODE COMPLIANCE AND THERMAL SHELL CHARACTERISTICS

This section discusses the survey results related to code awareness, code compliance and thermal shell characteristics.

6.1 RBES AWARENESS

6.2

About 35% of homeowners stated that their home complies with the RBES code. Another 25% of survey respondents had no opinion on code compliance, stating that they were unfamiliar with RBES. The RBES certificate was actually observed displayed in about 18% of the homes overall, as compared to the 25% of homeowners who claimed to have certificates in the phone survey. Not surprisingly, Vermont Star Homes program participants were more likely to report that their homes complied with RBES, and were more likely to have the RBES certificated displayed. As discussed in more detail in Section 6.2 below, four of the homes with RBES certificates displayed actually failed to meet the RBES standard by a fairly wide margin.

Table 6.1: Homeowners' Perception of RBES Compliance

	All Respondents		VT Star Home		Rated Homes	
	#	%	#	%	#	%
N	159		47		21	
say new homes complies	56	35%	31	66%	16	76%
say home does not comply	12	8%	2	4%	1	5%
not sure if home complies	51	32%	6	13%	3	14%
not familiar with RBES	40	25%	8	17%	1	5%
RBES certificate displayed	28	18%	19	40%	4	19%

6.2 RBES COMPLIANCE

Of the 158 homes in the sample, 92, or 58% +/- 8%, meet the standards of the Vermont Residential Building Efficiency Standard (RBES). Of these homes, compliance was determined for 139 using the VTCheck methodology of U values multiplied by the areas of building components to obtain UA values for all building components. Seventy-three of these homes were determined to meet the standard. Another 19 homes had received energy ratings through the Vermont Star program that demonstrated their compliance with RBES. Many homes are clustered around the RBES compliance criteria, with almost one third (51 homes) within 10% on either side of the RBES code.

The percentage of homes passing RBES shows an improvement over the 1995 baseline study, in which 35% to 40% of the homes were estimated to pass the RBES code. The characteristics of the homes failing to meet the standard were reviewed to assess any patterns in noncompliance. As in 1995, lack of foundation insulation, both basements and slabs, is a leading reason for failing to meet the code. A total of 53 homes lacked foundation insulation on at least some portion of their foundation and in 45 homes the area involved exceeded 20 feet of perimeter. Another major factor contributing to noncompliance was a high percentage of glazing and doors to wall area. About 40% of the homes that failed to meet the compliance criteria had window-to-wall proportions of 17% or greater. A less common reason for noncompliance was sporadic instances of missing or inadequate insulation in other envelope areas.

Figure 6.1: RBES Compliance

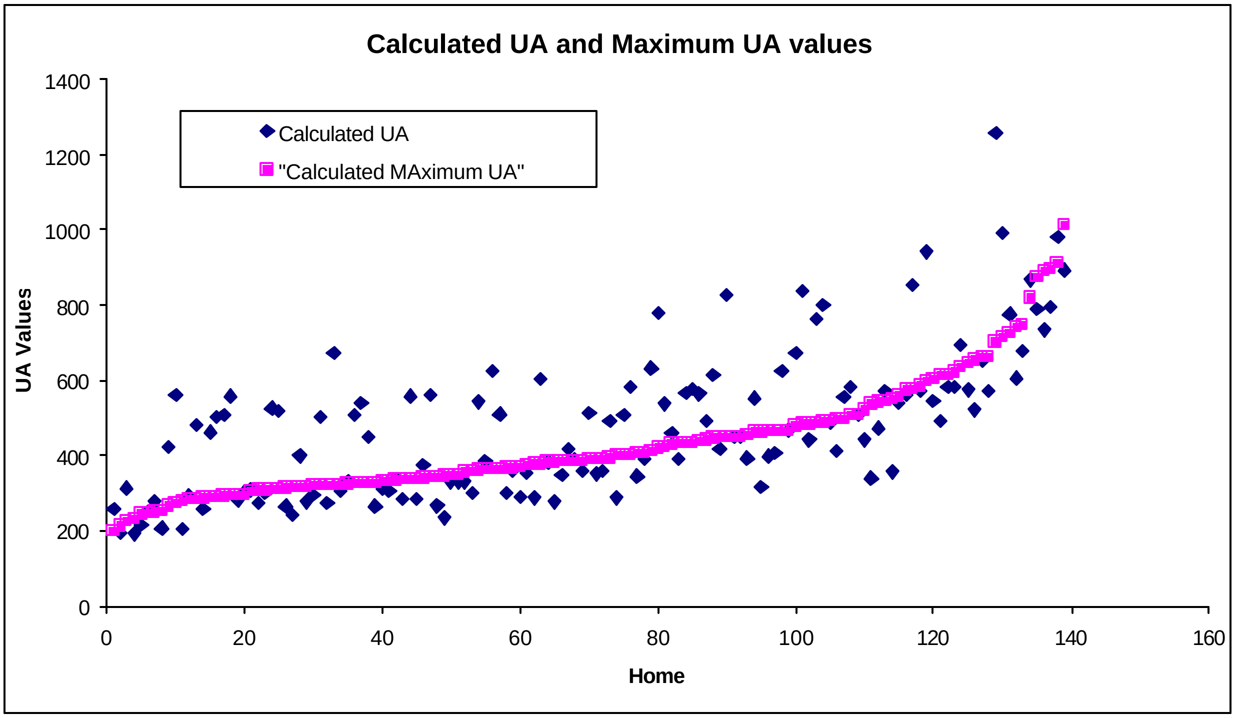


Figure 6.1 is a scatter plot of the UA values as compared to the code-required maximum UA values for each home, calculated for the 139 homes where complete data was collected. The Y-axis shows the UA values, and the X-axis represents each home, in order from lowest to highest allowed UA value. The purple line shows the minimum code compliance, and the dots represent

the actual homes; dots above the line are homes that do not meet the standard, while dots below or on the line comply with the standard.

Larger homes (over the median house size) passed at a higher rate than smaller homes (under the median), 65% to 51%, respectively. This result is significant at the 95% level. This difference may partially reflect a pattern in the results of the VTCheck software indicating that it is slightly easier for larger homes to pass than smaller homes.

Another noteworthy result is that eight of the 28 homes with RBES compliance certificates did not actually meet the code. Four of these homes were very close to passing (within 5%), and it is likely that these homes would have passed with an analysis based on more precise information (such as exact window U-values). However, the other four homes failed by a wide margin.

Homes built under Vermont's Act 250 passed the RBES standard at a nominally higher rate than the survey respondents as a whole, with 32 out of 48 homes (66%) meeting the code and compared to 56% for the non Act 250 homes. This difference in the rate of code compliance between Act 250 and those homes not identified as Act 250 is only marginally significant at the 10% confidence level.

In contrast, manufactured homes passed at a rate that was substantially lower than site built homes (41% as compared to 61%). This difference is statistically significant at the 95% confidence level.

Homes built by owner-builders are notable for their presence on both ends of the spectrum. Many of these homes were at the top of the efficiency ladder, and others were among the least efficient. Of the five homes that exceeded the code requirements by the greatest percentage (by VTCheck standards), three were built by owner builders, and two of the bottom five homes failing the code requirements by the largest margin were constructed by their owners.

6.3 OTHER RBES REQUIREMENTS

The RBES code includes some requirements beyond the thermal shell standard. This study was not designed to provide a comprehensive assessment of compliance with these additional requirements, due to time limitations and the other critical objectives of the site visits. However, the information collected through the site visits does provide some insight into compliance with these items, as list below in Table 6.2.

TABLE 6.2: ADDITIONAL RBES REQUIREMENTS

Other RBES Requirements	Description	Compliance Issues
Air Leakage	Seal joints, access holes, connections; standards for recessed lights	Houses generally very tight; only 28% over .31 air changes per hour; compliance with recessed light standard unknown
Vapor Retarders	Installed in all non-vented framing components	Attics generally vented; vapor barriers common in walls
Duct Insulation	Ducts in unconditioned space insulated to R-5	Ducts predominantly installed within thermal barrier; 1 home with uninsulated, unsealed ducts in unconditioned space
Duct Sealing	Ducts in unconditioned space must be sealed with mastic	See above
HVAC System Efficiency & Balancing	Minimum AFUE of .78 for furnaces, .80 for boilers; must have means for balancing	All homes met minimum AFUE requirement; no information on balancing is available.
Temperature Controls	Each HVAC zone must have a thermostat	All homes met this requirement
HVAC Piping Insulation	HVAC pipes insulated in unconditioned space	HVAC pipes predominantly installed within thermal barrier; 3 homes with uninsulated pipes in unconditioned space
Swimming Pools	Timer on pump, heater on/off switch and cover for heated pools	Only two homes with pools; compliance unknown
DHW	Meet minimum federal standard from 1992, minimum R-value of R-14; heat traps or pipe insulation for stand alone tanks.	All homes met federal standards; three homes had external tank wrap.
Fireplaces	Fireplaces must have one of the following: tight-fitted doors or chimney damper, or chimney cap damper.	50% of homes had fireplaces; about half of homes with fireplaces have tight doors, about two-thirds have designated air
Exhaust Fans	Dampers required for bath, kitchen and dryer fans.	Compliance unknown
Certification	Certificate displayed in home, sent to state and town clerk	Low certification rate (18% displayed in home)

6.4 MECHANICAL VENTILATION

VENTILATION

Of the 157 homes in the survey with complete ventilation data, 11 homes contained HRV's and 39 had exhaust fans on a timer control, for a total of 45 homes with a whole house ventilation system.[1] This result indicates that 29% of the homes had a whole house ventilation system, which represents a substantial increase from the 6% homes in the 1995 baseline study.

The majority of the ventilation systems are exhaust fans with timers. The increase in this type of ventilation seems to be largely driven by the efficiency programs, i.e., Vermont Star Homes Program, Vermont Gas's HomeBase Program, Washington Electric Coop's and Burlington Electric Department's residential new construction programs.[2] Table 6.2 shows that 70% of homes that were constructed with the assistance of one of these efficiency programs have a whole house ventilation system, as compared to 15% of the nonparticipating homes.

Table 6.3: Whole House Ventilation Systems

	All	Program Participants	Nonparticipants
N	157	50	107
HRV's	11	4	7
Exhaust fan/control	40	31	9
Total ventilation systems	51	35	16
% homes with ventilation systems	29%	70%	15%

Homeowners' perceptions: 34 homeowners (21% of the 157) reported that their homes had whole house ventilation. In eight (8) of these homes (24% of the 33), the homeowners indicated either that the control system was not used or that they were not familiar with the operation of the control system. (In at least one case, the auditor instructed the homeowner on the correct use of the controls.)

Comparing the homeowners' perceptions with the survey results showed that the 34 homeowners did accurately identify their homes as having a whole house ventilation system. In contrast, in 17 homes with ventilation systems, the homeowner apparently was unaware of it. Eleven of these homes were built by program participants.

[1] Some homes with HRV's also had an exhaust fan on a timer control.

[2] Whole house ventilation is required to meet the Vermont Star Home designation, and exhaust fans with timers are frequently recommended as a cost effective way to meet this standard. All of the programs have similar requirements.

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.5 Blower Door Test Results and Ventilation Issues

In general, the homes were tightly built, with over two-thirds of the homes below .31 natural air changes per hour. There were a very limited number of homes with infiltration problems.

Table 6.4: Blower Door Test Results

Natural Air Changes per Hour	Combined Total (# of homes)	ASHRAE Method[3] (# of homes)	ERH Method (# of homes)
N	156	137	19
Less than .31	103	84	19
.31 to .50	35	35	0
More than .50	9	9	0
Mean	.27	.28	.22
Median	.25	.26	.22
Minimum	.04	.04	.09
Maximum	1.00	1.00	.31

Although the homes are tight, they generally meet the ASHRAE Standard 62 guidelines for air flow at the current occupancy levels.[4] Only 6% of the homes failed to meet the standard and did not have a whole house ventilation system. In addition to the effectiveness of the efficiency programs in encouraging the installation of ventilation equipment, this result may also be an unintended consequence of the trend toward large homes.

If the homes are assumed to be fully occupied at two people per bedroom, 44 of the 156 or 28% fail to meet the ASHRAE criteria.

[3] The ASHRAE method involved averaging the results from pressurization and depressurization tests. Using this method allows comparison to the ventilation requirement set out in ASHRAE standard 62. The ERH blower door tests were based only on a depressurization test. More detail is provided in Section 4.

[4] Standard 62 requires 15 cfm per person. Consequently, the level of occupancy of the house has an impact on the air flow requirements.

For 136 homes, both pressurization and depressurization tests were performed (as discussed above). For almost all of these homes, these two tests produced different results, with the depressurization test higher in 39% (53) of the homes and lower in 56% (76). In a majority of the homes (63% or 85 homes), the cfm50 measurement made during the pressurization test was more than 10% different from the depressurization test, and in 17% (23 homes) the difference was 30% or more. The reasons for these differences are not readily apparent from the data collected in this study. These results indicate that averaging the two tests is likely to produce a more accurate assessment of air leakage than the depressurization test alone.

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.6 INSULATION LEVELS

Attic and wall insulation met or exceeded prescriptive code levels for the majority of homes. These results are similar to the 1995 baseline study, indicating that attic and wall insulation practices have not changed substantially since the RBES code was instituted.

As can be seen from the table below (Table 6.2), there is still room for improvement in attic insulation, with 36% of the slopes underinsulated in comparison to the minimum prescriptive code requirement. However, homes generally did not have multiple deficiencies in the thermal shell, i.e., these substandard conditions were sporadic and not found grouped in particular homes or types of homes. For example, a slope area in one home may have been underinsulated, but the attic flats and wall insulation levels were consistent with the RBES code or better. Also, a large majority of homes that failed to meet the RBES code had R-values close to the standard.

Walls were insulated to R-19 or better in 90% of the homes. This result is highly consistent with the 1995 baseline study, which found that 94% of the homes in that sample had R-19 or better in the main walls.

Table 6.5: Attic and Wall Insulation Levels

	Attic Flats	Slopes	Kneewalls	Walls
Total Homes	141	113	34	158
R-value Below Code	28%	36%	21%	10%
R-value Meet or Exceed Code	68%	64%	79%	90%
Minimum	15	19	0	8
Maximum	83	60	32	40
Median	38	30	19	19
Mean	40	32	19	20
Average Area (sq. ft.)[5]	1,115	775	297	1,931
Minimum RBES Requirement[6] (Prescriptive Path)	R-38	R-30	R-19	R-19

Comparison to the 1995 study suggests that basement insulation is becoming much more common. Over 60% of the homes in the current study had foundation wall insulation meeting the RBES minimum prescriptive level of R-10, as compared to less than half in the 1995 study.

However, even with these improved construction practices, basement walls were found without any insulation in about 25% of the homes, the slab edge of a walkout basement was almost always left without insulation and a number of homes had incomplete foundation insulation not reflected in the nominal R-values, i.e., a number of the homes that meet the nominal R-value requirement of the RBES code still have deficiencies in the basement insulation. Unlike attics and walls, most of the homes failing the RBES prescriptive standard had little or no basement insulation.

[5] Areas of the house components were not available for the 19 Vermont Star Homes participants for whom program data was substituted for direct data collection. The average area excludes these participants.

[6] The prescriptive code path allows for numerous ways to meet the code. These value represent the minimum and the builder may be required to increase the of other house components to meet the standard.

Table 6.5: Basement Insulation Levels

	Basement Walls	Exposed Floors	Floor over Unconditioned Space	Slab
Total Homes	146	26	45	63
R-value Below Code	38%	73%	67%	63%
R-value Meet or Exceed Code	62%	23%	33%	37%
Minimum R-value	0	8	0	0
Maximum R-value	29	43	45	11
Median R-value	10	30	28	0
Mean R-value	8	30	25	4
Average Area (sq. ft.) (see footnote 1)	1036	134	629	N/A
Minimum Code Requirement (see footnote 2) (Prescriptive Path)	R-10	R-38	R-30	R-10

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.7 WINDOW AND DOOR GLAZING

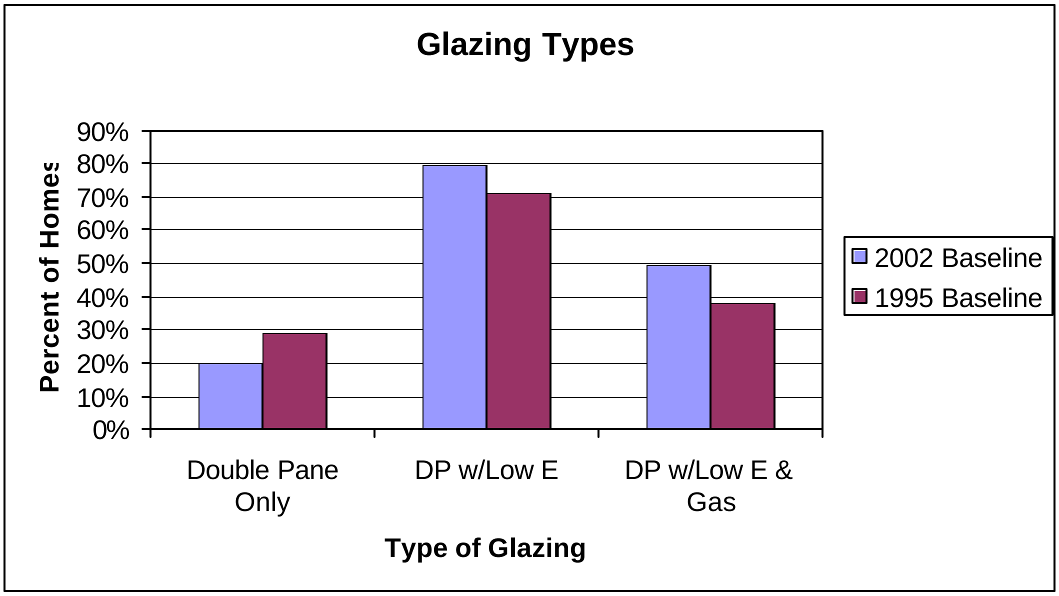
Double pane windows with Low-E glass is the most common choice for glazing among survey respondents, with about 80% of the homes having low-E glazing on 75% or more of their window area (126 of 158). High efficiency glazing with both Low E and argon gas were the predominant choice in about 50% (78) of these homes. The remainder of the surveyed homes (about 20%) had double pane without Low E or argon. The break out of the percent of glazing in windows and doors is depicted graphically in Figure 6.2.

Considering only the 139 homes that received full site visits, about 80% of all glazing area contained Low-E and 58% contained both low-E and argon gas. While windows with low-E and argon gas are a common occurrence, there were very few instances of higher efficiency windows such as triple pane with low E. Six door units and one window unit contained triple pane glass, for a total glazing area of 83 sq ft.

Single pane windows were rare. Only one home contained single pane windows with low E storms.

In comparison, the 1995 study indicated that about 70% of the homes had windows with low E and less than 40% had low E and argon. The increases in the percentages of Low E and gas filled windows between the 1995 and 2002 studies are significant at the 5% level. The results of the 2002 study indicate that the market has been continuing to move toward more efficient windows.

Figure 6.2: Glazing Types



While window efficiency has been improving, houses also have substantially more window area. In general, homes have a greater ratio of glazing to wall area than found in the 1995 study, as shown in Table 6.5 below. The 1995 study showed that almost a quarter of the homes had less than .10 glazing in comparison to the wall area, and only 15% of the homes had more than a .15 glazing ratio. In the current study, this trend is reversed, with only 10% of the homes having a glazing to wall area ratio of less than .10 and 35% of the homes having more than .15 glazing.[7]

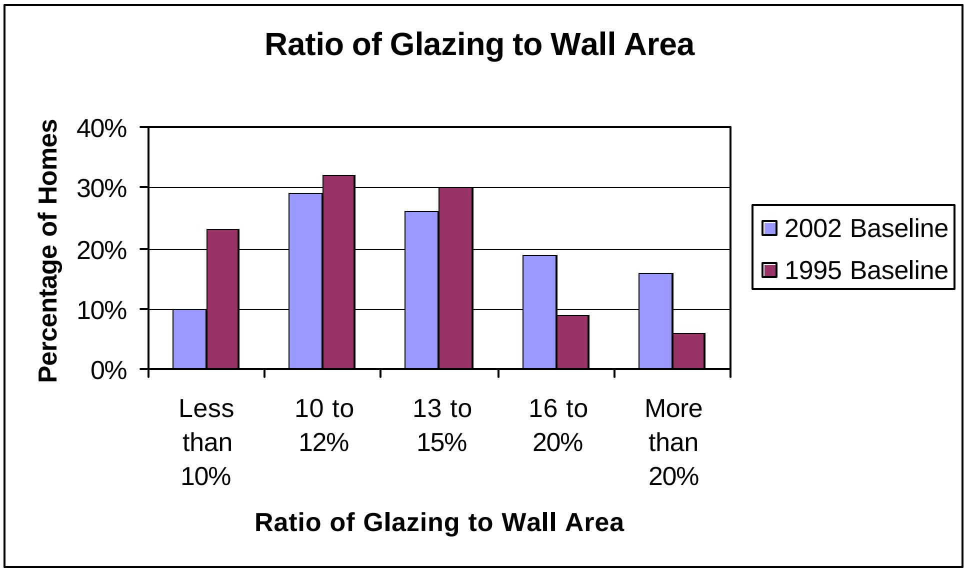
Table 6.6: Ratio of Glazing to Wall Area

	2002 Baseline Study		1995 Baseline Study
Window to Wall Area Ratio	Number of Homes	Percentage of Homes	Percentage of Homes
N	139		
Less than 10%	14	10%	23%
10 to 12%	41	29%	32%
13 to 15%	36	26%	30%

[7] The percentages for the 2002 study are based on the 139 homes with full site visits. There was not sufficient information to determine the percentage of glazing to wall area for the 19 homes where the shell data were obtained from the energy rating.

16 to 20%	26	19%	9%
More than 20%	22	16%	6%
Mean	6%		
Median	27%		
Minimum	14%		
Maximum	13%		

Figure 6.3: Graph of Ratio of Glazing to Wall Area



This trend toward higher glazing ratio is particularly prevalent in larger houses. The mean house size of homes with a glazing-to-wall ratio of less than .17 is 2380 square feet (99 homes), as compared to an average size of 2750 square feet for homes with .17 or more (40 homes). This difference between house sizes is significant at the 95% confidence level.